VI. Iowa/Cedar River Basin

A. Basin Description

The Iowa River and Cedar River basins have a combined area of 12,640 square miles, of which 11,590 square miles are in Iowa and 1,050 square miles are in Minnesota (Plate 63).The Cedar River basin covers 7,870 square miles, approximately 1,050 square miles of which are in Minnesota. In general, both basins are long and narrow. The slope of the Iowa River is 1.9 feet per mile and the Cedar River is 2.5 feet per mile. Both basins have a gently rolling topography with well-drained, highly productive soils that support the primarily agricultural economic base. The largest population center is Cedar Rapids.

The Iowa River's main tributary, the Cedar River, has its source in the marshy lowlands of glacial drift in Dodge County, Minnesota. The Cedar River flows in a southeasterly direction, roughly paralleling the course of the Iowa River for 300 miles in south central Minnesota and east central Iowa. It joins the Iowa River at the town of Columbus Junction, Iowa, 29.6 miles from the confluence with the Mississippi River.

B. Main Stem Hydrology/Hydraulics

1. Description of Flooding

Flooding in the Iowa River and Cedar River basins began in late March and early April, with near record flooding on the Cedar River at Cedar Rapids. Torrential rains continued during the summer of 1993 and the Cities of Cedar Rapids, Marshalltown, Waterloo, Conesville and Wapello experienced additional major flooding. Many of these areas were flooded in July and again in August as the relentless rains continued to cross Iowa. Plate 64 shows the total precipitation for May, June, July and August 1993 vs. average for the same period at Iowa City. There was some flood protection in some areas due to the local flood protection projects as well as to the operation of Coralville Dam. The details of the operation of the dam are discussed in Section D, Reservoir Regulation -- Coralville Reservoir.

Historical floods on the Iowa River have been well documented by the gaging station at Iowa City since 1908. A discussion of the historical floods is provided below. Table 19 shows the stations on the Iowa and Cedar Rivers and their top five floods of record.

a. Flood of 1851

The Flood of 1851 is generally recognized as the maximum flood of record on some of the Upper Mississippi River tributaries, including those in Iowa. It is the highest known flood on the Iowa River in Iowa City. Specific data regarding this flood are rather scarce.

b. Flood of 1881

The year of 1881 was the wettest year on record in Iowa with an average rainfall over the state of 44.2 inches. The City of Des Moines recorded 15.79 inches of rain for the month of June.

c. Flood of 1947

The characteristics of the rains occurring in 1947 were their wide area extent, long duration and large accumulated totals over the entire state. The rainfall over the state in June was, in general, from two to two-and-a-half times average, though that occurrence alone was not entirely responsible for the serious floods experienced. Contributing significantly to the flooding were the antecedent conditions of a saturated soil and rivers already swollen by a series of rains.

d. Flood of 1954

Heavy rainfall during the last few days in May and the first half of June thoroughly saturated the soil throughout much of the northern half of Iowa and produced conditions favorable for the occurrence of flood runoff from the heavy rains that were to follow. Streams in the upper Iowa River basin began rising to flood stages as a result of the heavy rainfall on June 15-19. Additional heavy rains of June 20-22 throughout most of the same area added runoff to the already swollen streams and produced heavy flooding.

e. Flood of 1969

Very heavy rainfall occurred in June amounting to 8 inches or more in the upper Iowa River Basin. This was followed by severe storms from July 6-9 with rainfall of 7.33 inches and 8.61 inches, respectively, at Iowa Falls and Eldora.

Table 19
Iowa and Cedar Rivers Top 5 Floods of Record

Station	Flood Stage	Date 1	Stage 1	Date 2	Stage 2	Date 3	Stage 3	Date 4	Stage 4	Date 5	Stage 5
Iowa River Rowan	N/A	6/17/84	15	6/21/54	14.88	4/1/93	14.69	5/18/91	14.01	7/18/93	13.37
Iowa River Marshalltown	13	8/17/93	20.77	6/18/90	20.47	3/31/93	20.26	6/5/91	20.13	3/19/79	19.77
Iowa River Belle Plaine	14.5	7/11/93	19.59	6/5/18	17.86	4/2/93	17.48	6/20/90	17.35	6/7/91	17.22
Iowa River Marengo	14.0	7/19/93	20.31	7/12/69	19.79	8/19/93	19.61	3/19/79	19.40	3/31/60	19.21
Iowa River Iowa City	26.0	1851	34.1	7/1881	31.10	6/8/18	29.60	6/17/47	28.6	8/10/93	28.52
Iowa River Lone Tree	15.0	7/7/93	22.94	9/22/65	20.27	5/19/74	19.97	5/5/93	18.77	4/22/93	18.14
Cedar River Waterloo	12.0	3/29/61	21.86	4/8/65	21.67	6/2/93	20.60	6/29/69	20.15	3/16/29	20.00
Cedar River Cedar Rapids	13.0	1851	20.00	3/18/29	20.00	3/31/61	19.66	4/4/93	19.27	4/4/33	18.6
Cedar River Conesville	12.0	4/6/93	17.11	6/18/90	16.90	4/12/65	16.85	7/7/93	16.83	4/2/61	16.62
Iowa River Wapello	20.0	7/7/93	29.53	6/18/90	28.91	4/22/73	28.63	5/19/74	28.12	4/7/93	26.60

2. Stream Data

Stage hydrographs have been prepared for selected Iowa and Cedar River gaging stations for the period March 1 through September 30. The stage hydrograph for the gaging station at Marshalltown on the Iowa River is shown on Plate 65. Flood stages were exceeded three times in March with the third highest level on record occurring on March 31. The peak stage reached was 20.26 feet. The river remained above the flood stage of 13 feet for the entire month of April and most of May. The heavy precipitation that occurred in June and July kept the river stage above 13 feet for most of June, all of July, all of August and half of September.

The hydrograph for the Iowa River gaging station at Belle Plaine, Iowa, is shown on Plate 66. Flooding in March occurred at the beginning and end of the month. April remained above flood stage for the entire month, and it was not until the end of May that the level dropped below flood stage. During that period the river reached the third highest stage on record of 17.48 feet. The summer rainfall brought the stage up again in June where it remained above flood stage until mid-September. The flood of record occurred July 11, reaching a peak stage of 19.59 feet.

The hydrograph for the Iowa River gaging station at Marengo, Iowa, is shown on Plate 67. The river was above flood stage for the entire period, with the exception of mid-March and mid-May, until the beginning of June. The second flood of record occurred July 19, reaching a peak stage of 20.31 feet. The fourth highest flood of record occurred August 19, reaching a peak stage of 19.61 feet. Flood stage is 14.0 feet. For the months April through September 1993 the runoff depth at Marengo, Iowa, was 28.2 inches. The mean runoff depth for the months of April through September for the period of record (36 years) was 5.5 inches.

The gage hydrograph for the Iowa River at Iowa City, Iowa, reflects the river regulation at Coralville Dam. The hydrograph shown on Plate 68 indicates that flood stage was not exceeded until July. The stage remained above the 26 feet flood stage until early September.

The hydrograph for the Iowa River at Lone Tree, Iowa, is shown on Plate 69. There are seven occurrences in which the level went above the 15-foot flood stage between March and June; however, each event lasted only a short period of time. The stage remained above 15 feet from July until the end of September. The flood of record occurred July 7 reaching a peak of 22.94 feet. The fourth and fifth floods of record occurred May 5 (18.77 feet) and April 22 (18.14 feet).

The hydrograph for the Cedar River gaging station at Conesville, Iowa, is shown on Plate 70. The shape of the hydrograph is very similar to the Belle Plaine and Marengo hydrographs. Generally, the levels are above flood stage except the middle of March, the end of May and the beginning of June. The flood of record occurred April 6 with the peak stage reaching 17.11 feet. Flood stage is 12 feet. The fourth flood of record was set July 7 reaching a peak stage of 16.83 feet. For the months of April through September 1993, the runoff depth at Conesville, Iowa, was 26.7 inches. The mean runoff depth for the months of April through September for the period of record (53 years) was 5.15 inches.

The Wapello gage is the most downstream gage on the Iowa River. Plate 71 shows the hydrograph at Wapello, Iowa. The shape of the hydrograph is similar to those for Conesville, Belle Plaine and Marengo. The flood of record occurred July 7 with the peak stage reaching 29.53 feet. The fifth highest stage occurred April 7 with a peak of 26.6 feet. Flood stage is 20 feet.

For the months of April through September 1993 the runoff depth at Wapello, Iowa, was 26.6 inches. The mean runoff depth for the months of April through September for the period of record (78 years) was 4.7 inches.

3. Hydraulics

Flooding on the main stem Iowa River from Iowa City and downstream was reduced due to the operation of the Coralville Dam. A detailed discussion of the reservoir regulation is provided in Section D, Reservoir Regulation-Coralville Reservoir. Table 20 is a summary of the stations along the Iowa River. This table compares the observed peak stages and discharges to the stages and discharges that would have occurred without the reservoir. Water surface profiles for the Iowa River from the mouth to Marshalltown, Iowa, are shown on Plates 72 through 76.

Table 20
Stage Reduction on the Iowa River From Operation of Coralville Dam

	Observed		**Reconstituted**		
Station	Stage (feet)	Flow (cfs)	Stage (feet)	Flow (cfs)	Reduction (feet)
Iowa City	28.5	28,000	30.1	39,000	1.6*
Lone Tree	22.9	57,000	23.9	65,000	1.0*
Wapello	29.5	111,000	#	#	0.7*

(# Final analysis pending.) *Estimated

C. Tributary Hydrology

1. Description of Flooding

a. Timber Creek

Timber Creek has a basin watershed area of 118 square miles. The gaging station for Timber Creek at Marshalltown, Iowa, has a period of record extending from 1949 to current year. The Flood of 1993 ranked fourth highest of the top five events. On July 9, the peak stage reached 17.03 feet. Flood stage is 13 feet. Other notable events were as follows: 1977 (17.69 feet); 1974 (17.57 feet); 1982 (17.30 feet); and 1947 (16.80 feet).

b. Richland Creek

Richland Creek has a drainage basin area of 56.1 square miles. The Richland Creek gaging station at Haven, Iowa, has a period of record that extends from 1949 to current year. Flood stage is 21 feet. The third highest flood occurred on July 17, reaching a stage of 22.84 feet. Other significant events were as follows: 1991 (26.71 feet); 1974 (23.03 feet); 1977 (22.56 feet); and August 29, 1993 (22.39 feet).

c. Salt Creek

Salt Creek at Elberon, Iowa, has a drainage area of 210 square miles. The gaging station at Elberon has a period of record that extends from 1945 to current year. Salt Creek set a new flood of record July 9, reaching a peak stage of 20.85 feet. Flood stage is 9.5 feet. The remaining of the top five events are as follows: 1982 (20.00 feet); 1944 (19.90 feet); 1992 (18.82 feet); and 1990 (17.88 feet).

d. Walnut Creek

Walnut Creek has a basin area of 70.9 square miles. The gaging station for Walnut Creek at Hartwick, Iowa, has a period of record extending from 1949 to current year. The 1993 Flood ranked fourth at this station. On August 29 the stage rose to 16.76 feet. Flood stage is 12 feet. The other noteworthy events are as follows: 1991 (16.93 feet); 1983 (16.65 feet); 1977 (16.30 feet); and 1979 (16.00 feet).

e. Big Bear Creek

Big Bear Creek has a basin area of 189 square miles. The Big Bear Creek gaging station at La Dora, Iowa has a period of record from 1945 to current year. Flood stage is 20 feet. The top five floods recorded at the La Dora gage are as follows: 1977 (25.32 feet); 1960 (24.60 feet); August 30, 1993 (24.69 feet); July 25,1993 (24.00 feet); and 1982 (23.91 feet).

f. Clear Creek

Clear Creek has a basin area of 98.1 square miles. The gaging station for Clear Creek at Coralville, Iowa has a period of record from 1952 to current year. July 6, 1993, the flood stage reached 14.74 feet, its second highest flood of record. Other significant events are as follows: 1990 (16.36 feet); 1982 (14.61 feet); 1974 (13.93 feet); and 1970 (13.49 feet). Flood stage at this station is 10.8 feet.

g. Old Man's Creek

Old Man's Creek basin area is 201 square miles. The gaging station at Old Man's Creek at Iowa City, Iowa, has a period of record that extends from 1950 to current year. Old Man's Creek set new records during the flood of 1993. The flood of record occurred on July 6 reaching a stage of 17.61 feet. The other new record occurred on July 24 (17.02 feet) ranking the fourth highest on record. The three other notable events occurred as follows: 1982 (17.25 feet); 1990 (17.20 feet); and 1965 (15.55 feet).

h. English River

English River has its source in Poweshiek County, near Grinnell, Iowa. It flows east southeasterly for approximately 84 miles and enters the Iowa River at mile 53.8 upstream of the mouth. The watershed covers an area of about 645 square miles and the channel has a slope of

4.7 feet per mile. The English River at Kalona experienced the flood of record during the 1993 event. On July 6, a new flood of record occurred at 22.55 feet. Flood stage is at 14.0 feet. The period of record at this gage is from 1939 to current year. Other events of significance are as follows: 1965 (21.45 feet); 1974 (20.17 feet); 1990 (20.07 feet); and 1974 (19.97 feet).

D. Reservoir Regulation - Coralville Reservoir

1. Pre-Flood Conditions

The base conditions for the flooding at Coralville Reservoir started in 1992. The cooler than average growing season resulted in low evaporation rates and saturated soils at the end of summer. Fall was wetter than average, and the soils remained saturated at the onset of winter. Winter was cold and cloudy, and by late spring nearly a 4 inch water content snow remained on the ground. Details of the antecedent conditions are discussed in Chapters II and III. Coralville Reservoir was maintained at its conservation pool (683 feet NGVD) from January 1, through February 15. At this time, the pool was drawn down to 679 feet in accordance with the regulation plan (Table 22). During this period, the average inflow was 1,690 cfs, 51 percent above the average inflow of 1120 cfs.

2. Reservoir Operation

a. March

The Coralville Reservoir inflow-outflow-pool elevation hydrographs for the months of March through September are shown on Plates 77 through 83. The plates show the inflow-outflow hydrographs for the Coralville Reservoir. The following paragraphs discuss the details of that operation. Snowmelt and precipitation increased Iowa River flows in March. Rainfall at the dam of 0.65 inch on March 3 and 0.18 inch on March 4 combined with snowmelt to raise inflows to a peak of 14,200 cfs March 8. Downstream flows were monitored to meet the regulatory constraints at Lone Tree of 16.0 feet (18,000 cfs) and Wapello of 22.0 feet (36,200 cfs). These constraints were approached March 5 when cutbacks to near 1,000 cfs were made at the dam. A combination of these events caused the pool to raise to 695.85 feet March 12. A drop in the inflows allowed the pool to be drawn down to 688.6 feet March 22. Rainfall March 21 and 22 (0.56 and 0.67 inch, respectively) and warm days raised the inflows above 11,000 cfs for several days and raised the pool above 690 feet for the rest of the month. Continued warm weather produced additional snowmelt and high base flow conditions kept inflows near 10,000 cfs and the pool above 690 feet.

b. April

Rainfall of 0.55 inch recorded at the dam March 31 increased already high inflows to a peak of 23,900 cfs April 4. This occurred concurrently with high flows at Lone Tree and Wapello causing releases to be cut to 1,000 cfs from April 4 - April 8. The pool rose to 707 feet April 8. This required changing the category of the operation plan to Major Flood (Table 22). Outflows were gradually increased to 10,000 cfs, and inflows remained high. The pool peaked at 709.34

feet April 11 and remained above 709 feet for the rest of the month with outflows held at 10,000 cfs. As specified in the Major Flood Operation Plan, the outflows were not reduced in spite of high stages at the downstream control stations. An additional 1.11 inches of rain, recorded April 20, caused inflows to rise above 13,000 cfs at a time when the pool was starting to fall. Instead, the pool rose to 710 feet April 24, and gradually fell to 709.23 feet by the end of the month as inflows remained high due to rain during the last week of the month.

c. May

In May, under normal conditions, the operation plan is changed to growing season constraints at the downstream stations. Releases are made to limit the Lone Tree gage to a stage of 14.0 feet and the Wapello gage to a stage of 21.0 feet. These constraints were not enforced at the beginning of the month in accordance with the Major Flood Operation Plan. Rainfall recorded on each of the first eight days in May totaled 2.69 inches at the dam. This interrupted the gradual fall in the pool elevation and, instead, raised it to 709.14 feet May 4. High releases of 10,000 cfs quickly resumed a gradually falling pool as inflows fell from 10,800 cfs May 7 to 6,230 cfs May 21. The pool dropped below 707 feet and the Major Flood provisions of the operation plan were no longer required. Outflows gradually were reduced to 7,000 cfs by the end of the month as inflows fell to 3,520 cfs despite 2.12 inches of rain recorded at the dam in the second half of the month.

d. June

By June 4, the outflows were down to the maximum release allowed during the growing season when not in Major Flood operation (6,000 cfs). The inflows remained above 3,500 cfs. Rainfall recorded June 5 at the dam (0.59 inch) increased the inflows to 7,000 cfs. On the morning of June 8, the dam recorded a total of 1.64 inches of precipitation, with the entire lower river basin experiencing rainfall amounts between 0.5 inch and 1.5 inches. This caused the inflows to raise above 10,000 cfs. Lone Tree and Wapello gages both went above their growing season constraints and the outflow was cut back for two days on June 8 and June 9. The inflow rose to 11,400 cfs and the pool to 704.7 feet by June 16. For two days ending June 19, the drainage area upstream of the dam received 0.5 inch of rain over the entire area with some places getting more than 2.3 inches. The dam received 0.11 inch June 18 and 2.63 inches June 19. This storm centered near the dam produced 1.35 inches of rain at Lone Tree over a two-day period. The next day 0.3 to 1 inch of rain fell over the whole river basin. This intense rain raised the inflows to 17,000 cfs June 21 and caused the reservoir to go over 707 feet early June 20, returning the regulation to the category of Major Flood Operation. Some 1.31 inches of rain occurred on June 25. This rain was not widespread upstream but did keep inflows high as the pool went above 711 feet late June 25. Coralville's regulation plan provided for rapid increase in release rates between 711 feet and 712 feet from 10,000 cfs to 20,000 cfs. Another heavy rain occurred, centered near the dam, with 2.45 inches of rain by 6 a.m. June 27. By the end of June, the pool was at 711.5 feet with an outflow of 12,000 cfs and an inflow of 11,400 cfs.

e. July

July 4 brought 2.21 inches of rain on a already high pool. The entire upper basin received between 0.45 inch of rain at Marshalltown to 4.43 inches at Marengo. The next day another 1 inch of rain fell over the basin. Coralville Dam's spillway overtopped for the first time in its history on the morning of July 5. High flows in Iowa City and downstream of Wapello caused great concern over the outflows for downstream residents. Inflows averaged 35,700 cfs July 5. Outflows July 5 increased from 13,200 cfs to 17,400 cfs during the day. On July 6, the inflow fell to 22,800 cfs and the outflow remained at 17,400 cfs. Inflows fell to 14,700 cfs July 7 and to 14,400 cfs July 8. Outflows increased July 7 to 18,100 cfs, and after a peak pool elevation of 713.4 feet, the pool slowly fell to 712.58 feet July 10 after a peak July 7 of 713.40 feet. Recorded rainfall the morning July 9 was 1.34 inches at the dam, 3.5 inches at Marshalltown, 2.6 inches at Elberon and 1.91 inches at Belle Plaine.

High inflows predicted for the already full reservoir raised concerns of flooding of the Iowa City and University of Iowa Water Treatment Plants, downstream of the dam. Reservoir operations were modified so as to limit the opening of the conduit. Discussions between Rock Island District and the City of Iowa City continued. Inflows rose as follows: 19,700 cfs July 10; 29,000 cfs July 11; 34,000 cfs July 12; and 32,000 cfs July 13. The inflows remained high for several days, falling to 21,400 cfs July 17 and peaking again July 19 at 36,000 cfs (USGS record peak discharge 39,000 cfs).

Rapid and Clear creeks both flow into the Iowa River between the reservoir and Iowa City. These creeks, as well as the gage at Iowa City, were closely monitored for the remainder of July and into August. It was determined that the water treatment plant would not be inundated if the stage at Iowa City remained below 28.5 feet. The dam was operated to maintain 28.0 feet at Iowa City. The outflow regulation goal at this time was intended to get as much water out of the reservoir as possible but still protect the water treatment plants. If heavy rain were observed in Clear Creek or Rapid Creek drainage areas, the releases from the dam would be reduced. After the flow from the two creeks peaked and started to fall, the outflows were increased. Outflows remained near 24,000 cfs most of the time, cutting back to 20,000 or 21,000 cfs to protect Iowa City as necessary. As the lake level rose, more flow went over the spillway increasing the total outflow of the reservoir. To protect the Iowa City water treatment plant, this excess flow was taken into account by cutting back on the releases from the conduit.

The pool reached its peak for the summer at 716.71 feet on July 24, 129 percent of total flood control storage, representing 3.52 inches of runoff. Full conduit outflow was reached for the first time July 30 with the pool at 713.30 feet. The next day heavy rainfall (2.38 inches) fell at the dam and within the basin increasing flow in Clear Creek and Rapid Creek. The outflows were reduced to protect the water treatment plant. By midnight, flow in the creeks had crested and fallen enough to return full conduit outflow.

f. August

Full conduit outflow was maintained for the first eight days of August. The pool fell below the spillway crest of 712 feet August 1. Despite 0.71 inch of rainfall recorded the morning of August 6, the pool continued to fall, dropping below the Major Flood level of 707 feet on the morning of August 9. Heavy rainfall August 9 caused rapid rises on Clear and Rapid creeks.

The release from the dam was cut from 18,000 cfs to 13,200 cfs at 5 a.m. August 10. The Iowa City gage recorded a peak of 28.41 feet and the water treatment plant was saved. The rainfall recorded on the morning of August 10 was 4.12 inches at the dam, 2.72 inches at Iowa City and 3.06 inches in Coralville. Rainfall, late August 11, resulted in a small reduction in the releases at Coralville Reservoir from 16,500 cfs to 13,400 cfs. More rain on August 14 and 15 of 0.12 and 0.91 inch caused increased flows on the downstream tributaries of Clear Creek and Rapid Creek and a reduction in the releases from 16,700 cfs to 13,000 cfs. On both occasions, Iowa City stage remained well below the 28.0 foot constraint. Inflows to the dam increased and a storm ending August 16 produced significant amounts of rainfall recorded throughout the basin. The dam had 2.15 inches; Iowa City, 1.63 inches; Coralville, 1.51 inches; Kalona, 1.99 inches; Old Man's Creek, 2.23 inches; and the upstream stations recorded from 1.4 to 3.12 inches. The resulting runoff caused the inflows to reach 32,000 cfs on August 19 and the releases were cut from 16,400 cfs to 12,500 cfs on August 16 to protect Iowa City. By the evening of August 18, the conduits were again fully opened though the high inflows caused the pool to continue to raise, peaking at 711.62 feet on August 22. Heavy rainfall at the end of the month, 0.96 inch over a three-day period at the dam, increased inflows while outflows were reduced to protect Iowa City. The pool fell to 707.85 feet the morning of August 29. It peaked at 708.42 feet the evening of August 31 before inflows fell off and the conduit was again fully opened.

g. September

Fully opened conduit flow was maintained until September 11 when the outflow was reduced to slow the rate of the fall in pool elevation. This was done to protect against bank sloughing upstream of the dam. The pool continued to fall with reductions in the outflow made as necessary until September 24. At this time the pool had reached the normal fall conservation pool operating limits of 686 feet, and the outflow of 5,300 cfs was nearly equal to the inflow of 5,000 cfs. Table 21 summarizes some of the most significant regulation events that occurred during the 1993 Flood.

Table 21
Significant Events During 1993 Flood Regulation at Coralville Lake

Date	Pool	Remarks
June 30	711.5 feet	Increased outflows to 12,000 cfs in accordance with plan
July 5	712.0 feet	Exceeded spillway, outflow 14,000 cfs
July 12	714.0 feet	Followed plan until July 11. Adjusted releases to control for 28.0 feet on Iowa City gage outflow 22,000 cfs
July 19	715.7 feet	Max 1993 outflow 25,800 cfs
July 24	716.7 feet	Maximum reservoir elevation
August 1	712.0 feet	Lake level below spillway

Table 22
Coralville Reservoir
Regulation Plan

Regulation Schedule	Condition	Operation
A. Conservation Storage	I. Normal	Regulate pool level as nearly as possible without adversely affecting downstream conditions as follows: Date — Operation 15 Feb - 1 Mar — Lower from 683 to 679 1 Mar - 15 Jun — Hold elev. 679 15 Jun - 15 Sep — Hold 683 15 Sep - 15 Dec — Hold 683 - 686 15 Dec - 15 Feb — Hold 683 Do not release less than a minimum outflow of 150 cfs, except as specified in Schedule D, nor exceed releases specified in Schedules B & C.
B. Flood Control	I. 15 December to 1 May	Maintain pool levels specified under Schedule A as nearly as possible without exceeding release of 10,000 cfs except as limited by Conditions B.III, B.V and Schedule C.
	II. 1 May to 15 December	Maintain pool levels specified under Schedule A as nearly as possible without exceeding release of 6,000 cfs except as limited by Conditions B.IV, B.V and Schedule C.
	III. 15 December thru 1 May. Stage at Lone Tree or Wapello are at, above, or forecasted to exceed 16.0 feet or 22.0 feet respectively.	Reduce release to not less than 1,000 cfs to control flow to those discharges at respective stations insofar as possible during 3 days of crest at respective station, except as limited by Schedule C.
	IV. 1 May to 15 December. Stage at Lone Tree or Wapello are at, above, or forecasted to exceed 14.0 feet or 21.0 feet respectively.	Reduce release to not less than 1,000 cfs to control flow to those discharge at respective stations insofar as possible during 3 days of crest at respective station, except as limited by Schedule C.
	V. Any date, stage at, above or forecasted to exceed 18.0 feet on Mississippi River gage at Burlington, Iowa.	Reduce release to 1,000 cfs during 7 days corresponding to crest flow in the Mississippi River with due allowance for time of travel, except as limited by Schedule C.

Table 22
Coralville Reservoir Regulation Plan
(continued)

Regulation Schedule	Condition	Operation
C. Major Flood	I. Rising reservoir any date Reservoir elevation is above or forecasted to exceed elevation 707.0 feet.	
	i) Inflow has not peaked.	i) Determine the increased outflows necessary to prevent reservoir from exceeding elevation 712. Release not more than outflows shown below: 15 Dec - 1 May: Elev. / Outflow — 707 / 10000; 708 / 10000; 709 / 10000; 710 / 10000; 711 / 10000; 711.1 / 12000; 711.2 / 13000; 711.3 / 14000; 711.4 / 15000; 711.5 / 16000; 711.6 / 17000; 711.7 / 18000; 711.8 / 19000; 711.9 / 20000 1 May - 15 Dec: Elev. / Outflow — 707 / 7000; 708 / 8000; 709 / 9000; 710 / 10000; 711 / 11000; 711.1 / 12000; 711.2 / 13000; 711.3 / 14000; 711.4 / 15000; 711.5 / 16000; 711.6 / 17000; 711.7 / 18000; 711.8 / 19000; 711.9 / 20000 712 all gates fully open
	ii) Same condition as above except inflow has peaked.	ii) Determine the minimum outflows required to utilize the remaining storage below 712.0 feet and set release at that flow or the present outflow whichever is higher.
	II. Reservoir falling.	Release outflows established by C.I.ii until elevation 707 is reached; then gradually reduce flows to Schedule B operation as deemed necessary by inflow and downstream conditions.
D. Drought Emergency	I. Any date the reservoir elevation is between 677.0 and 678.0.	Reduce release to 100 cfs.
	II. Any date the reservoir elevation is below 677.0.	Reduce release to 75 cfs.

3. Runoff vs. Storage Volume

The Flood of 1993 consisted of a series of storms over many months without enough time to evacuate stored water between events. Table 23 shows the runoff going into the reservoir with respect to the amount of runoff stored or evacuated in a given month. The flood control storage in Coralville at the top of flood pool, 712.0 feet NGVD, is equivalent to 2.62 inches of runoff. The total runoff coming into the pool for the period March 1 through September 30 was 30.3 inches, or more than 11 times the total flood storage available at the dam. The peak one-day inflow for 1993 had a frequency of once in 20 years (5 percent), the 30-day peak inflow had a frequency of once in 200 years (0.5 percent) and both the 90-day and 120-day inflows were estimated to be greater than the once in 1,000-year event (0.1 percent).

Table 23
Coralville Reservoir
Runoff vs. Storage Utilized in Inches

Date	Total Runoff	Storage Utilized	Incremental Change in Storage
March 31, 1993	1.92	0.58	+0.58
April 30, 1993	4.60	2.41	+1.83
May 31, 1993	2.73	1.70	-0.71
June 30, 1993	3.60	2.70	+1.00
July 31, 1993	7.73	2.90	+0.20
August 31, 1993	6.00	2.28	-0.62
September 30, 1993	2.75	0.57	-1.71

4. Sedimentation

The most recent sediment surveys that were used to determine storage for Coralville Reservoir were conducted in 1983-84. The impact of the 1993 Flood on reservoir storage cannot be determined at this time.

5. Problems and Lessons Learned

The Coralville Reservoir water control operation for the summer flood flows of 1993 was complicated by unregulated flash flooding from Clear Creek and Rapid Creek. Coralville Reservoir is designed to protect the Iowa City-Coralville area. This required good communication between the Corps of Engineers and Iowa City. It was also important to communicate to the public regular updates of the situation.

A new Standard Operating Procedure for flash flooding below Coralville Reservoir is being developed. When Clear Creek or Rapid Creek have a flash flood, the telemarks (LARCS) on those streams will send a message to the Rock Island District office. Procedures of communication will standardize the operation in the event of emergencies.

Ratings of outflow structures should be more stable than tailwater discharge estimates. Therefore, in the future it may be advantageous to base reservoir outflows on structural ratings. This could be achieved by installing instrumentation on the sluice gates so the gate settings as well as the pool elevations would be available for satellite transmission to the Rock Island District Water Control Center. Consistent computation of reservoir outflows would then be determined from the flows though the gates and over the spillway.

VII. Skunk River Basin

A. Basin Description

The Skunk River basin extends from near the north central region of Iowa to the Mississippi River in the southeast. The drainage area is 4,355 square miles, as shown on Plate 84. The topography within the basin is gently rolling with elevations ranging between 518 feet and 1,200 feet. Nearly all of the basin land is farmland, with 77 percent used as cropland. The general shape of the basin is long and narrow with a length of 180 miles and a maximum width of 40 miles. The average width is 24 miles.

The Skunk River splits into two main channels in Keokuk County forming the North Skunk and the South Skunk rivers. From Ames to the eastern Mahaska County line, the Skunk River floodplain is relatively wide, reaching a maximum width of about two miles in Polk County. In Keokuk, Washington, Jefferson, Henry, Des Moines and Lee Counties, the river meanders through a narrow floodplain. Upstream of Ames, the river has not been altered, and the floodplain is relatively narrow.

B. Hydrology/Hydraulics

1. Description of Flooding

The flooding in the Skunk River basin was catastrophic in Ames, Iowa. The total precipitation at the Ames NWS station for May, June, July and August 1993 compared to the average for each of those months is shown on Plate 85. A tributary to the Skunk River, Squaw Creek, reached record heights and flooded Iowa State University's Hilton Coliseum with 14 feet of water. Plate 86 shows the stage and flow hydrographs for the storm that flooded several Iowa State University buildings. Squaw Creek rose from a stage of 5 feet to a stage of 18.5 feet in eight hours. Table 24 is a summary of the top five floods of record in the Skunk River basin.

Table 24
Skunk River Basin Top 5 Floods of Record

Station	Flood Stage (feet)	Date 1	Stage 1	Date 2	Stage 2	Date 3	Stage 3	Date 4	Stage 4	Date 5	Stage 5
South Skunk River at Ames	7.0	8/16/93	14.23	5/20/84	13.90	6/10/54	13.66	6/13/47	11.95	6/17/93	11.84
Squaw Creek at Ames	9.0	7/9/93	18.54	6/17/90	15.97	6/4/18	14.50	3/27/75	14.00	6/13/84	12.97
South Skunk River at Oskaloosa	15.0	1944	25.80	7/15/93	24.78	6/23/90	22.98	2/7/73	22.52	6/19/84	21.76
N. Skunk River at Sigourney	16.0	6/20/90	25.37	3/31/60	25.33	7/6/93	24.68	6/14/66	23.85	4/25/76	22.80
Skunk River at Augusta	15.0	4/23/73	27.05	4/3/60	25.00	9/24/65	24.90	7/10/93	23.70	5/20/43	23.00